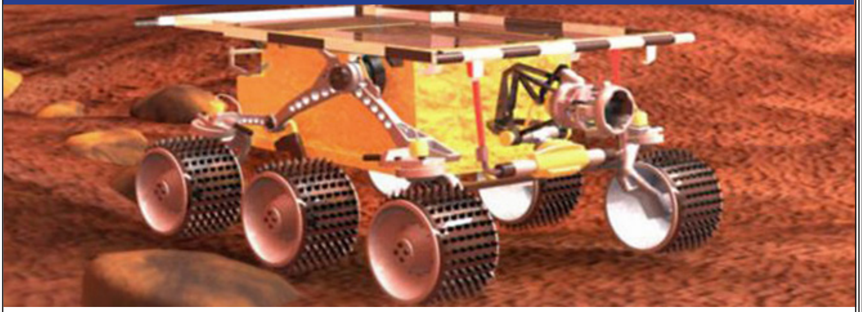
SHOEBOX Rover



You are a born engineer! Human beings have always found ways to help us work and explore. Our earliest machines were simple, but key to our survival. A spoon, a hammer, an arrow. As technology evolved, we invented more complex machines. Plows, wheelbarrows, bicycles. Eventually, we designed machines that perform amazing jobs. Now we even explore the outer edges of our solar system. Yowza!

SHOEBOX ROVER

Explore cool NASA inventions. Build engineering skills. Get your hands dirty. Work in a team. Have fun! How? Design your own Shoebox Rover. What do you need? Curiosity. Time. Craft materials:

- Explore
- Create
- Collaborate
- Problem-solve
- Build a Rover!

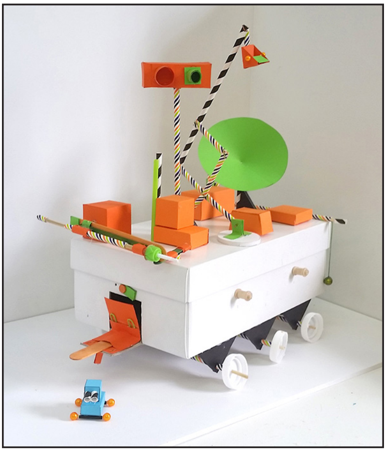
SIMPLE MACHINES

It all starts with six simple machines. Levers, wedges, screws, pulleys, wheels and axles, and inclined planes. Combine these simple machines and do more complex jobs! Every NASA spacecraft uses simple machines in its design.

THE SIX SIMPLE MACHINES

- Levers
- Wedge
- Screw
- Pulley
- Wheels & Axle
- Inclined Plane

GO! The Spacecraft Bus

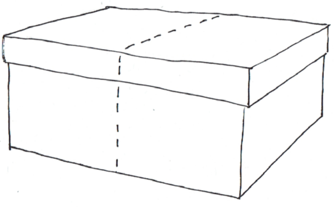


What's life's home base? Our body! The skeleton offers structure. Skin gives protection. Outside, sensors gather information. Eyes, ears, nose, tongue, skin. Inside, we process. We take in food & oxygen & water for energy. Our brain is mission control.

Think of a spacecraft like a robot. A human-like robot, going places hard for humans to visit. It needs a lot of the same things. The spacecraft body is often referred to as a "bus" or a "chassis." Its structure is the skeleton. It carries all the working parts of the mission, from engine to camera to satellite dish. It protects instruments from the harsh space environment.

An explorer robot's shape and construction depends on its mission. Where is it going? What questions does it hope to answer?

1. GETTING STARTED:
A shoe box will be your rover bus. It will house your mechanical parts & instruments.
    - Collect all materials
    - Construct your box if necessary
    - Use templates or measure to find the center line around the top and bottom as shown.



Note: Remember, the lid will be slightly larger than the box when you make your measurements.

WHEELS & AXLE: Automota

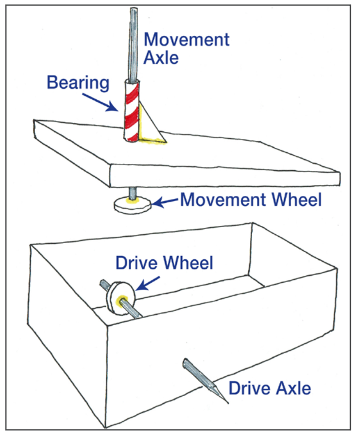
ADDING MOTION

Rotating parts allow an instrument on a NASA spacecraft to take advantage of its position. You will make two "automata" (ah-TOM-a-tah)—moving instrument mounts—for your rover. An automaton uses wheels and axles inside the shoebox to transfer movement to the outside. Cardboard circles that connect at a 90-degree angle, like gears, move your instruments.

1 PUNCH YOUR HOLES

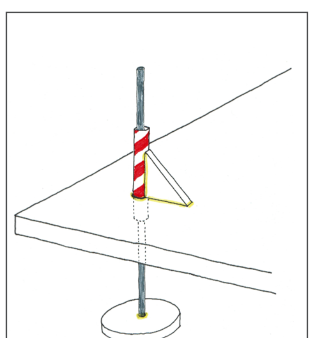
Each set of motions (automaton) needs two aligned holes on the long sides of the box, and one hole through the lid.

- Measure your box or use the templates provided for hole placement on the long sides.
  - A horizontal skewer goes through the box sides for the drive axle, parallel to the floor. It should be able to spin freely.
  - A vertical skewer goes through the top of the box for the movement axle.

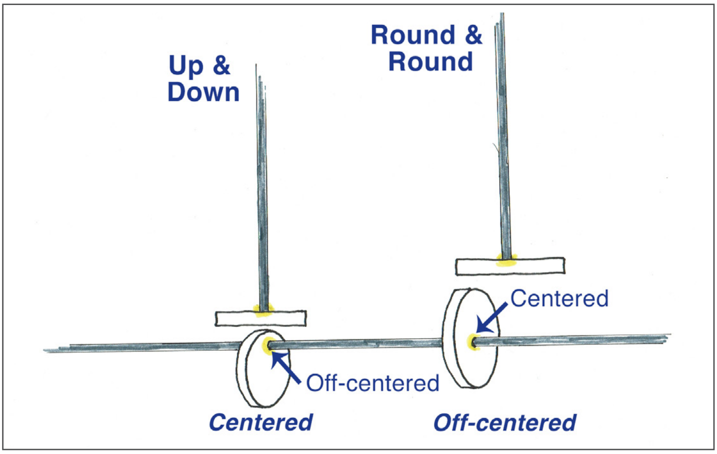


2 BRACE YOUR INSTRUMENTS

- Glue a 3" paper straw through each top hole so that it sticks down inside the box about 1/4". This will be the bearing for the axle.
- Glue a right triangle connecting your straw and top of your box. This braces your vertical axle.



AUTOMATA: Choose Your Movements



3 **CHOOSE YOUR MOVEMENTS:** Instruments (Camera! Antenna and dish!) on the top of your rover can go round & round or up & down. Look at the sketch to understand where to place the axle on the drive wheel for the desired movement.

4 **PUTTING IT ALL TOGETHER**

- Glue movement wheel to end of movement axle
  - Place through straw bearing in lid.
- Poke drive wheel onto drive axle
  - Round & Round is centered
  - Up & Down is off-center
- Place drive wheel on axle so the movement wheel rests on it perpendicularly
  - Round & Round is off-center
  - Up & Down is centered

TIP: Cut a little door in your shoebox to help you see. It can become an opening for another instrument!

TEST MOVEMENT

When movement on rover top is what you want it to be:

- Secure drive axle ends using a spool or binder clip
  - Glue one side of the axle.
  - Snug close to rover (limits side to side movement)
  - Trim skewer and secure 2nd side
- Glue drive wheel in place on axle

WHEELS & AXLE: Locomotion

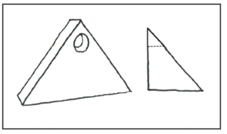
Robotic spacecraft help us explore distant worlds. We design them to interact with their surroundings and gather data. Moving parts and locomotion can be key.

A wheel (or two) is placed on a shaft called an axle. The axle goes through a straw bearing. This structure supports the axle and allows it to spin freely.

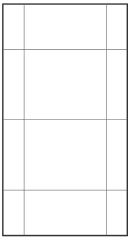
1 LOCOMOTION DESIGN:
For smooth locomotion, Shoebox Rover axles and bearings are parallel with the ends of the box.

Skewers = Axles
Plastic lids = Wheels
Straws = Bearings
Triangles = Struts

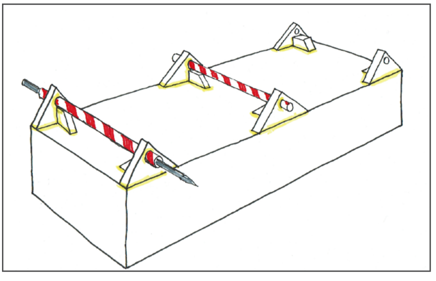
- For 3 sets of wheels and axles
  - Struts: Cut 6 right cardboard right triangles
  - Punch hole with regular punch
  - Braces: six small right triangles



- Measure and draw lines on the bottom of the box, as shown
  - Glue the struts to the bottom of the box
  - Center on the horizontal lines, parallel to box sides

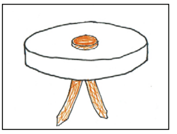


- Connect a straw bearing to opposite struts. Glue to secure.
  - Glue braces to inside of struts
  - Slide axle through straw bearing. Do not glue! Axles must spin freely.
- Poke a hole through the center of each wheel.
  - Add wheels to the axles
  - Trim skewers
  - Glue to secure



MOVE, PIVOT, TURN!

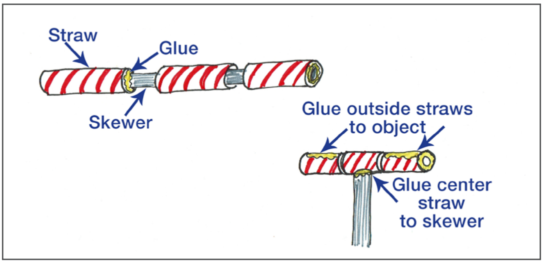
MORE APPLICATIONS: Wheels and axle can be incorporated into other instruments to make them move, pivot and turn! Explore examples of swivel mounts (which hold instruments on the box) and hinges. Customize your rover design with detail and creativity.



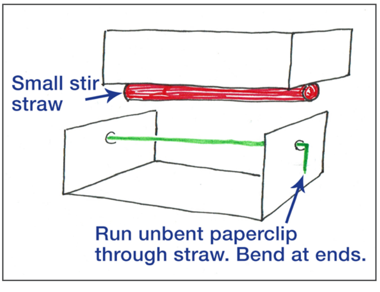
2 SWIVEL MOUNT

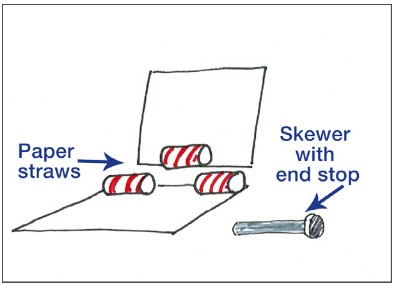
- Punch a hole on rover where instrument is wanted
- Punch hole in the center of a cardboard circle (wheel mount)
- Connect with large brad at top (axle)
- Glue instrument to wheel, leaving it free to move on the axle

3 HINGES



A hinge is a movable joint made with an axle and bearing attached to two separate objects. This allows them to pivot and turn. Paper or small stir straws can be used for your bearings. Skewers or paperclips make great axles.



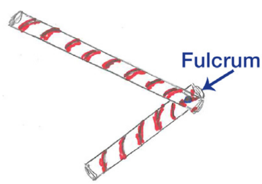


LEVERS

In ancient Greece, Archimedes once said: "With a long enough lever, I can move the world!" Levers are simple machines we use everywhere. Our earliest inventions were levers. Sticks. Brooms. Spears. Many have another simple machine on them, like a wedge. This helps them dig, cut and do work. You even have levers in your body. Think joints and limbs. Find levers on your body!

When we send robotic explorers to places people cannot go, we often equip them with levers. Robotic arms are complex machines that use a series of levers. They perform a range of tasks, from collecting samples to moving science instrument.

1 EXPLORE LEVERS

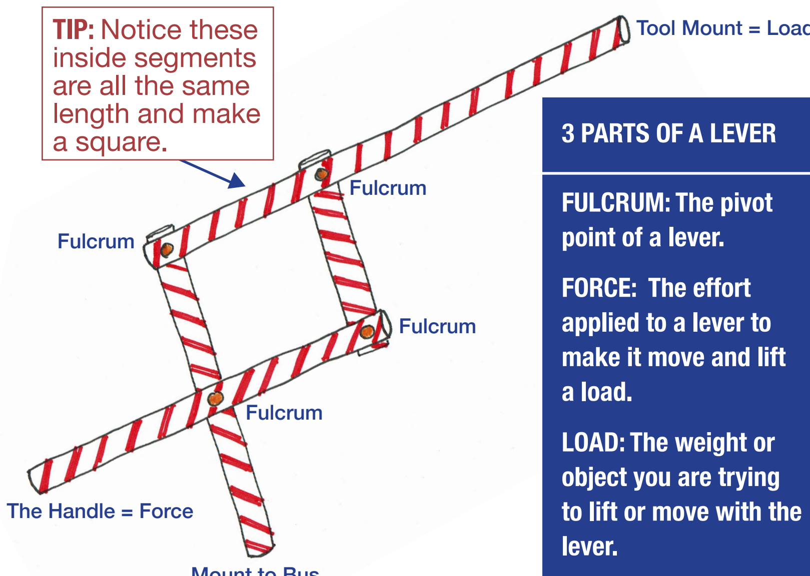


Make a lever out of two straws:

- Put a dot of glue in one end of each & squish
- Punch a small hole at the end
- Connect with a small brad—this is your fulcrum
- Make another!

How might two levers combine to make a robotic arm?

TIP: Notice these inside segments are all the same length and make a square.



3 PARTS OF A LEVER

FULCRUM: The pivot point of a lever.

FORCE: The effort applied to a lever to make it move and lift a load.

LOAD: The weight or object you are trying to lift or move with the lever.

PIVOT, TURN, & TOUCH

DESIGN CHALLENGE: Make a robotic arm! What work do you want it to do? Collect soil or air or liquid samples? Move an instrument? Or solar panels, a drill, a secret hatch? Its purpose will help you decide the best design.

DESIGN YOUR LEVER ARM:

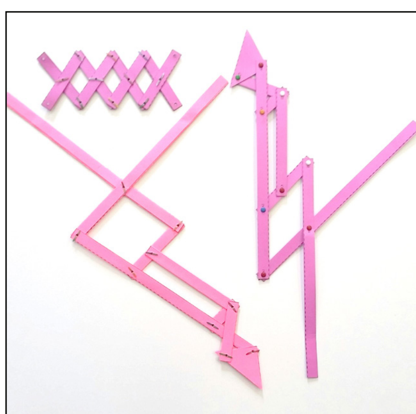
- Design your robotic arm (sketching ideas helps)
- Construct it
- Mount it to your rover

See Wheels & Axle: Swivel Mount

LEVER PRACTICE

Hone your making skills with our lever templates.

- Print (ideally on cardstock
- Cut out
- Score fold lines with
- Embroidery needle
- Fold & glue
- Punch holes
- Match hole #'s
- Connect with tiny brads



WEDGES

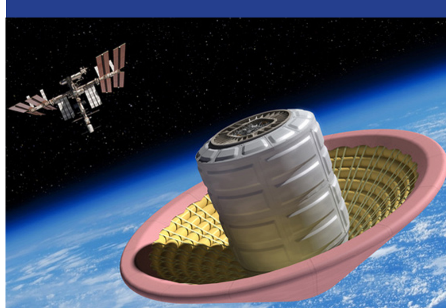
Wedges are simple machines that help us cut, scoop and collect. Look around your kitchen or garden and you'll see many examples. Knives. Spoons. Shovels. A wedge is often combined with other simple machines. With a handle as a lever, it scoops. Two wedges that meet in a point can be an inclined plane.

Many wedges are used on NASA spacecraft. Mars Sojourner Rover had rows of wedge teeth on its tractor-like treads to give it traction as it moved on the Red Planet's surface.

Wedges can be found in the form of scoopers and shovels on many Mars rovers, including Spirit, Opportunity and Curiosity. The new Mars lander, InSight, has a wedge shaped projectile carrying a thermometer probe. It will be deployed into the Martian surface to take its temperature.

SPACE WEDGES

Wedges in the form of nose cones, fins, wings and heat shields are used in spacecraft to make them aerodynamic. Their angled shape helps them cut through the atmosphere. Projectiles, from spears to jets to rockets, use wedges to assist with flight. NASA is designing a inflatable heat shield to protect spacecraft entering the Martian atmosphere that is a mushroom-shaped wedge!

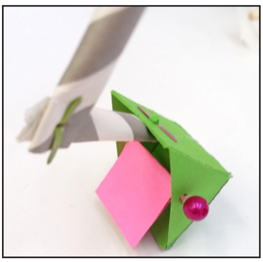


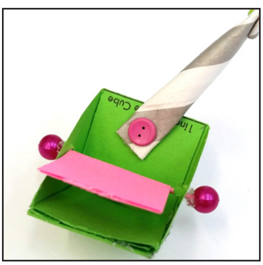
CUT, SCOOP, & COLLECT

DESIGN CHALLENGE: Design an instrument for your lever arm using wedges. If your lever arm is like your own arm, what do you want its "hand" to do? Your tool could be a pick, ax, shovel, or even a temperature probe. Get creative!

Think about:

- The science data you want to collect
- The work you want your arm to do





❶ DESIGN WEDGE TOOLS:

Our rover's wedge tool is a shovel. We made it by converting a 1" cube. Experiment with other 3D shapes. Add special details.

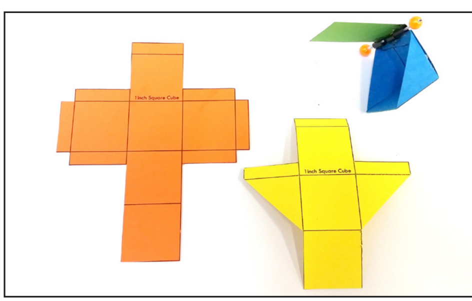
Ideas:

- Create a lever cover with a paper clip axle and 2 beads
- Add a brad or hinge assembly at the end of your arm for range of motion
- Place several instruments on one rotating mount as a turret

TO MAKE A SHOVEL

Choose a 3D template:

- Cut the side squares at a diagonal (see yellow template)
- Remove the last end square
- Fold and glue tabs



Add a hinged cover.
Use a stir straw as a bearing and a paper clip for an axle.

INCLINED PLANES

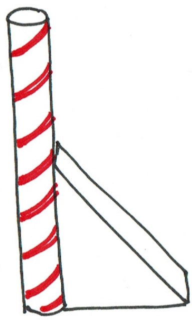
Inclined planes are flat surfaces tilted at an angle, like a ramp. They help workers get heavy loads into and out of trucks. They are wheelchair ramps and pedestrian walkways. Even animals create inclined planes— think of the zigzag pathways deer make to climb hills.

The inclined plane's angled surface is key to its usefulness. It reduces the force needed to lift a load straight up by distributing it over distance. But there is a trade-off. The greater the slope of an inclined plane, the shorter the distance you have to go. But it takes more effort to get there.

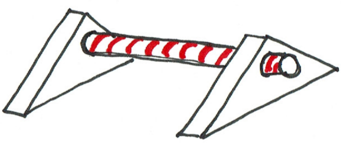
NASA missions like Path Finder had an inclined plane ramp to deploy the first Mars rover, called Sojourner. And rovers need to maneuver up and down inclined planes as they explore rough terrain.

TRIANGLES, BRACES, & SUPPORTS:
Because inclined planes are great at distributing force along their angled surfaces, they make good supports. Braces secure your engineering components.

AXLE SUPPORTS:
A paper straw with cardboard or foam core right triangles are used to support your vertical skewers.

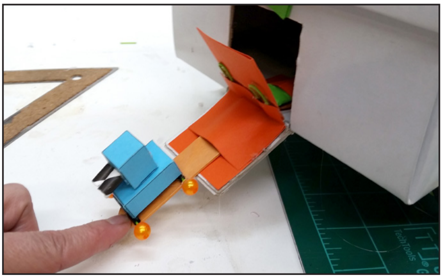


AXLE BRACES:
Cardboard or foam core triangles can position and support your wheels and axles. A bearing made out of a straw is attached to hold your axles. See Wheels and Axles.



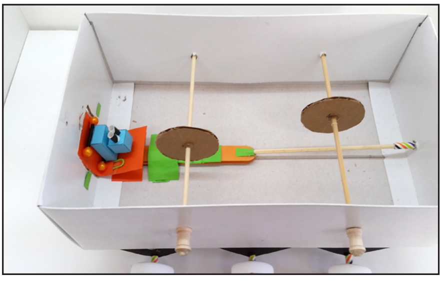
MOVE & BRACE

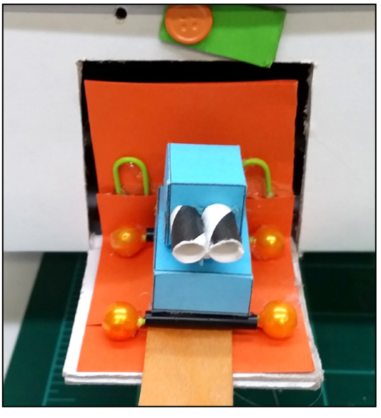
DESIGN CHALLENGE:
Design an inclined plane ramp for your rover.
Be creative!



Ideas:

- A trap door that opens down to make a ramp to deploy a mini rover
- Create a system to push your instrument out the trap door with a retractable arm or lever



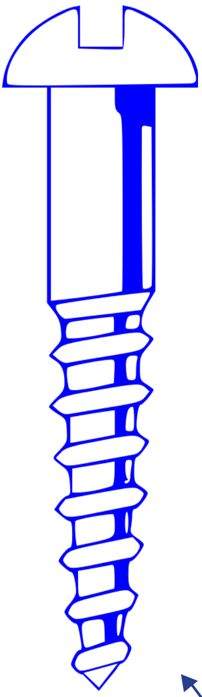


1. **MAKE A MINI TOOL:**
Design a mini instrument for your ramp. Our mini rover is housed in a secret compartment. It has a prism body and paper straw cameras. Stir stick bearings, paper clip axles, and beads are the wheels. There's even a lever latch!

SCREWS

Screws are simple yet amazing machines. They are made by wrapping an inclined plane around a cylinder (what...?).

A screw's spiraled edges are called threads. They work to distribute force when turned, twisting them into material like earth or wood. Many NASA rovers employ a drill system for sample collection and geologic analysis.



NASA missions use many screws to assemble and connect spacecraft parts. Space shuttle astronauts used a robotic drill to repair the Hubble Space Telescope. The brilliant engineering behind this drill has made space repair missions much safer and effective for astronauts. More complex machines like propellers, helicopter blades and fans are also screws that spin around and cut through air or water.

CHALLENGE:
Examine the image above. Draw an arrow to other simple machines you see that are part of a screw's design.

Hint: Think wedge!

ROBOTIC GEOLOGISTS

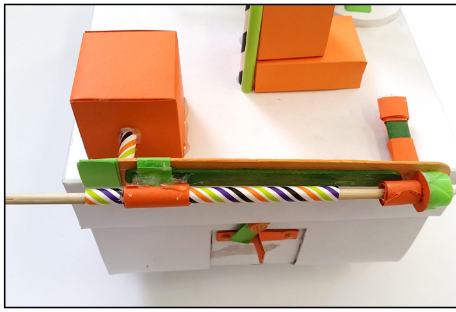
Landers and rovers have simple and complex machines to do the job of a geologist. Spirit and Opportunity used an instrument called the Rock Abrasion Tool (RAT) which was the first instrument to drill into the interior of another planet. Curiosity has a more sophisticated drill system that works in tandem with a suite of instruments and on-board lab to analyze the Martian surface.

DRILL, CUT & CONNECT

DESIGN CHALLENGE:
Design an instrument that uses a screw.

Consider:

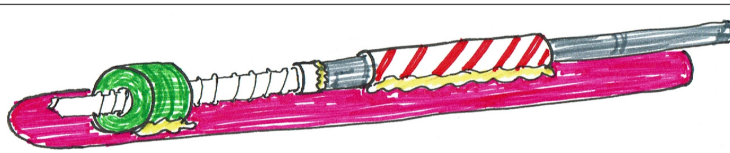
- The science data you want to collect
- The work you want your arm to do



You can use the insides of an old glue stick or Chapstick for the screw itself, as well as screws from the family toolbox.

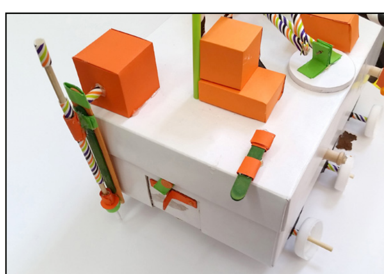
1 DESIGN A DRILL:
For our example, take apart an old glue stick and use the screw and threaded cap parts.

- Glue a skewer axle to the end of the screw
- Make a straw bearing
- Glue the bearing and the threaded cap to a popsicle stick
- Spin your stick and the screw will move up and down!



Glue threaded cap of glue stick to popsicle stick

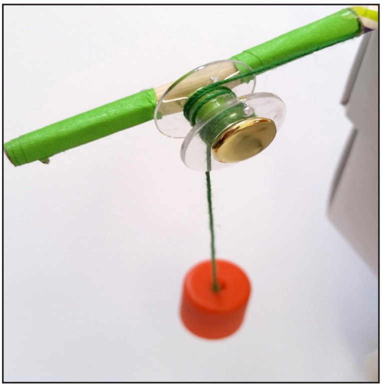
2 ADD DETAILS:
Use your simple machine knowledge to add custom details.
A rotating lever mount and holder are interesting ideas. Have fun experimenting!



PULLEYS

A pulley is a simple machine that combines a wheel and axle with a line like a rope or chain. It is used to raise and lower a load. Pulleys are important in construction and transportation. Think cranes, large and small. Sailboat lines. Bicycle gears. Fishing rods.

A single fixed pulley is helpful directing a line. Combine more than one pulley and you reduce the force needed to shift that load. Use two pulley wheels and it takes half the force to do the same amount of work! That's called a mechanical advantage.



DESIGN CHALLENGE:
Your challenge is to design a pulley system for your rover to do a task. Think about what type of instrument you would like it to lift and move. Experiment with one or more pulleys.

ULTIMATE CHALLENGE:
Make your rover your own. Use your new design mindset and making skills to:

1) envision the world your spacecraft will investigate
2) decide the science questions you want to answer
3) design the instruments and tools you need

Have a blast, you engineer you!

SPACE PULLEYS

NASA has made ingenious use of pulleys in the design of several missions. Mars Science Laboratory used an innovative sky crane to lower the Curiosity rover to the red planet's surface in mid-air. The new Mars InSight lander has a cool pulley system combined with a robotic arm. It will place a temperature probe, seismometer and cover on the Martian surface.

MOVE & LIFT

1. **DESIGN YOUR PULLEY SYSTEM:**
Your challenge is to design a pulley system to do a task. What instrument on your rover would benefit from one? Experiment with one or more pulleys.

2. Pulley: start with a bobbin wheel
    - Insert a piece of plastic straw into bobbin for the bearing
    - Place brad through the straw for the axle
    - Open brad tabs and tape to the end of a skewer
    - Bobbin should spin freely

3. Pulley line
    - Tie a bead around your string
    - Wrap it around bobbin for a counter-weight

4. Instrument
    - Construct an instrument (3D templates)
    - Tie to the other end of string for the load

5. Assembly
    - Slip your skewer and string through a straw
    - Glue the straw to your box
    - Glue your skewer to straw to secure
    - Beware: don't glue the string!